Per the recent request by the EPA, this memo addresses issues that the EPA raised in February 1999 and documented in a February 10, 1999 letter from Ms. Deborah K. Wood of the EPA to Randall Evans of Infineum and Peter Chant, consultant to Infineum .

In the EPA letter nine general points were raised. This document comments on each in the order they were presented.

EPA Comment #1: "To the extent possible, a detailed description of the theory and principles behind the impact of Vektron® on motor vehicle emissions. Uncertainties regarding the nature and affect of pertinent variables on Vektron®'s impact on CCD and emissions should be addressed in your planned test program."

Infineum response to Comment #1) Vektron 6913 impacts gasoline powered vehicle emissions in two ways. First, by providing superior intake valve and fuel injector detergency, it gives all the emissions control expected from the CAAA 1990 § 211 (l) regulations. Second, Vektron 6913 offers additional componentry that acts in the combustion chamber to reduce NOx without impacting CO or HC tailpipe emissions.

Haury and Graham (SAE 961098) have shown that Vektron additives containing this componentry give 10-20% higher CCD mass than base fuel alone, while lowering NOx emissions. The conclusion from this data is that the component provides this benefit through some mode other than CCD cleanliness. The discussion of the potential modes of action have been provided by Infineum separately. To summarize, NOx is formed in the high temperature regimes in the combustion process. Vektron can act by lowering the high temperature either through a free radical quenching mechanism or by altering the thermal conductivity of the deposits. Indeed, as cited by Lee (SAE 1999-01-3583, pg. 15) this reduction of heat transfer to the coolant is the predominant mechanism for NOx increase.

Additional discussion re CCD will be addressed in points 4, 5 & 6.

There existed at the beginning of the program design uncertainties regarding intermittent use of the additive (see 7)and vehicle types including such parameters as age, displacement, and targeted emissions standard (see 2 & 3). Considering the target for the test program results, actual mileage duration of the test was another uncertainty (see 8).

EPA Comment #2: "A detailed description of how vehicle technology variables affect the impact of Vektron® on emissions.

> What vehicle technology variables other than those used to define the technology types under the reformulated gasoline (RFG) program (i.e., fuel delivery type, EGR, catalyst type, & air injection) would tend to influence the impact of Vektron® on emissions? Given the mechanisms by which Vektron® affects emissions (see #1), and that these mechanisms depend on mileage accumulation (rather than being instantaneous effects as under the RFG program), other, yet-to-be-defined technology variables may significantly influence the impacts of Vektron® on emissions. In some cases, this influence may be so strong as to result in an impact on emissions that is directionally different for different vehicle models."

EPA Comment #3: "Support for the selection of the vehicle models that would be used in a program to evaluate the emissions impacts of Vektron®, and the method by which the results from such a program would be extrapolated to predict the response for a broader group of in-use vehicles. The discussion regarding points #1 & 2 should be drawn upon here."

Infineum response to Comments #2 & #3) During test design discussions, staff at the EPA OTAQ felt that focus on vehicle technology type may not be the most robust method for studying the applicability of the Vektron on the current and near term fleet. The staff felt that composing the test fleet of a broad spectrum of in use vehicles based on sales volume would far better represent the impact of the additive in real world situations. Twenty-eight vehicles representing seven vehicle types were chosen with guidance from both OTAQ staff and outside industry experts from major automotive manufacturers. These types included three emission standards, three vehicle types (trucks, SUVs and passenger cars) and engine designs (V-8, V-6, I-4) and seven different displacements as shown in "Vektron® 6913 Gasoline Additive NOx Evaluation Fleet Test Program" documentation. If the additive were to show a benefit in this fleet staff felt that it would translate more readily to the whole fleet than any engine technology type sorting could.

EPA Comment #4: "Support for the mileage accumulation cycle to be used in a test program to quantify the emissions impacts of Vektron®, and for the use of data generated using this cycle to predict the in-use impacts.

> City-type driving may tend to promote the formation of CCD. Engine soaks may also influence the formation of CCD. Rapid accelerations and high-speed operation can promote the removal of CCD."

Infineum response to Comment #4) There are a large number of mileage accumulation cycles that could have been employed. Some of them are proprietary while others have been published. The OTAQ staff felt that only a public domain cycle would be appropriate and one had already been published in the Code of Federal Regulations for use for emissions durability testing. Thus the cycle shown in the "Vektron® 6913 Gasoline Additive NOx Evaluation Fleet Test Program" was used.

EPA Comment #5: "A detailed description regarding how fuel variables influence the impact of Vektron® on emissions.

> Since the higher boiling fractions in gasoline may have the most effect on the tendency of gasoline to form CCD, the potential impact of differences in T90 distillation point (and potentially the end-boiling point) should be specifically addressed. Since gasoline aromatics content may influence the character/composition of the CCD formed, the potential impact of differences in gasoline aromatics content on Vektron®'s impact on emissions should be specifically addressed. The review of the technical literature will help to identify other fuel parameters which may need to be considered."

EPA Comment #6: "Support for the composition of the base gasolines used in a test program to evaluate the impacts of Vektron® on emissions, and a discussion of how test data from base fuels of a given composition would be used to predict the impact of Vektron® on emissions for in-use gasolines of varying composition. The discussion regarding points #1 & 5 should be drawn upon to address this point."

Infineum response to Comments #5 & #6) The role of combustion chamber deposits (CCD) in increasing vehicle tailpipe NOx has been an area of study for a long time. Kalghati published a review of the literature (SAE 952443) in 1995. It is well established that total removal of CCD will reduce NOx emissions. The nature of the relationship of deposit build up to NOx increases continues to be an area of investigation. Whether the relationship is linear or not continues to be investigated. Lee (SAE 1999-01-3583) has shown that the relationship is a step function with the contribution of CCD to NOx reaching a plateau after a set mileage. That mileage is unique to vehicle and type and usage pattern. He showed that vehicles reach this plateau in less than 10,000 miles. Kalghati describes the CCD formation in the cylinder as a dynamic process where the amount of deposit can vary within a range depending on a number of factors. Lee also showed that reducing the CCD thickness, but not removing it, showed no decrease in NOx emissions.

The CRC was interested in the shape of the NOx/CCD curve. Their recently published study (CRC Report No. 624 "Effects of Combustion Chamber Deposits on Vehicle Emissions and Fuel Economy") stated "Because the "mid" and "high" CCD-forming fuels produced almost the same levels of CCD, it is not possible to reach a definitive conclusion about the shape of the emissions versus CCD relationship".

Extensive review of the current literature concludes that there is no clear understanding of the CDD versus emissions relationship. There may exist a point at which removal of deposits gives a reduction in emissions, but there is no clear understanding of where exactly that point exists if it exists at all.

Infineum has postulated that Vektron acts by some method other than reduction of CCD levels and has shown the reductions in an extensive fleet to a high degree of statistical significance.

As far as the gasoline parameter contribution to CCD, Woodyard & Lee (SAE 1999-01-3582) showed that no single gasoline parameter was a good predictor of CCD. Indeed they feel that "more complex physical-chemical models are required".

Colucci et. al. (SAE 1999-01-3584) concluded that Ca RFG is the best gasoline for emissions characteristics. Therefore, even if concerns exist about the potential for CCD differences from fuel affecting the results, the fuel used in this test would be expected to give the most conservative results.

EPA Comment #7: "A discussion on how the intermittent use of Vektron®-additized gasoline would influence its impact on emissions.

> How might the mixture of other detergents with Vektron® influence the Vektron effect? Are there existing or potential fuel additives which would degrade the effectiveness of Vektron®?"

Infineum response to Comment #7) The test was designed to show how the additive would work under intermittent use conditions. See Section II in Infineum "Vektron® 6913 Gasoline Additive NOx Evaluation Fleet Test Program".

EPA Comment #8: "A discussion on how the mileage-dependant nature of Vektron®'s impact on emissions would be evaluated.

- This discussion should include consideration of how Vektron® would impact emissions at different mileage accumulation levels.
- Discuss how the dynamic process of the formation and removal of deposits (some formed with gasoline containing additives other than Vektron®) would influence Vektron®'s impact on emissions.
- To what extent would deposits formed while using other detergents need to be replaced by "Vektron® deposits" for Vektron® to have its beneficial effect on emissions? How quickly would this happen?

Infineum response to Comment #8) The OTAQ staff decided that the most appropriate mileage for this test would be to mimic the proposed use pattern. If the additive was to be used only during an "ozone season" then the test should be of a duration typical of that season. It was decided that 1000 miles per month represented a typical VMT. Although there are variations in ozone season duration around the country, eight months was deemed average. The test mileage was then chosen to be 8000 miles.

All the cars used in the test were employed after at least 15,000 miles of usage. It was felt that the cars were past the CCD ramp up stage described in the literature and that the dynamic loss/renewal pattern was in control.

A discussion of how long it would take for the Vektron to provide the full benefit took place at the end of the test. The conclusion from the data was that the Vektron ramp up would require about 1000 miles or one month.

EPA Comment #9: Support for the choice of a baseline detergent additive against which the benefits of Vektron will be evaluated. The baseline detergent additive should be representative of the technologies currently used with respect to its effect on combustion chamber deposits.

Infineum response to Comment #9) The baseline gasoline additive contained a synthetic carrier and the same detergent as Vektron 6913 and delivered the same level of detergency in the finished fuel. This additive was chosen so that intake system cleanliness was equalized throughout the test. Thus any differences shown would be attributable to the unique Vektron 6913 componentry.

Lastly, any concern that this additive could contribute significant differences of CCD thus skewing the results are unfounded. Most et. al. showed (SAE 982716) that additive packages containing pibamine detergent and synthetic carrier (identical in type to the reference additive used in this test) gave CCD levels statistically no different than base fuel. Further bench testing showed that these type additives gave CCD levels equivalent to both base fuel and base fuel containing PEA detergent.

Conclusion

The test performed by Infineum under the guidance of the EPA OTAQ staff demonstrated a statistically significant NOx reduction. At all decision points the most conservative approach was chosen. Given the uncertainty in the underlying science, a robust empirical study was performed. This design is sufficiently flexible that it could be used with small modification to evaluate any gasoline or gasoline additive technology for emissions benefits.